OPERATIONAL MODELING AND DATA ASSIMILATION STUDIES OF THE NORTH ATLANTIC AND THE COASTAL ZONE

George L. Mellor
Program in Atmospheric and Oceanic Sciences
P.O.Box CN710, Sayre Hall
Princeton University
Princeton, NJ 08544-0710
phone: (609)258-6570 fax: (609)258-2850 email: glm@splash.princeton.edu

Tal Ezer
Program in Atmospheric and Oceanic Sciences
P.O.Box CN710, Sayre Hall
Princeton University
Princeton, NJ 08544-0710
phone: (609)258-1318 fax: (609)258-2850 email: ezer@splash.princeton.edu

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LONG-TERM GOALS

The long term goals of the study are: 1. To develop a high resolution basin-scale model with data assimilation capability for the prediction of meso-scale features in the North Atlantic ocean, and 2. to test and improve the operational Coastal Ocean Forecast System of the U.S. east coast.

OBJECTIVES

The scientific objectives are to evaluate the capability of high resolution models of the Gulf Stream, the coastal zone and the North Atlantic to simulate the variabilities of observed oceanic properties, and to develop and test data assimilation methodologies in order to improve nowcast/forecast systems that combine different data sources with realistic dynamic models. In particular, a challenging task is the implementation of data assimilation methods in a real-time operational forecast system.

APPROACH

The modeling and data assimilation studies use the sigma coordinate, free surface Princeton Ocean Model (POM, Blumberg and Mellor, 1987). Under previous ONR support, POM has been configured for different domains and different resolutions, from a high resolution regional coastal model (Mellor and Ezer, 1991) and a Gulf Stream model (Ezer and Mellor, 1994a, 1997b) to a lower resolution North Atlantic (Ezer and Mellor, 1994b) and a whole Atlantic Ocean model (Ezer and Mellor, 1997a). The high resolution models have been used for nowcast/forecast and data assimilation studies, and have been the basis of a real-time operational Coastal Ocean Forecast System (COFS, Aikman et al.,

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1996), whereas the low resolution models have been used for climate variability studies. In recent years, the research has been focused on intermediate basin-scale North Atlantic models that can resolve mesoscale variability in the Gulf Stream and the Gulf of Mexico regions, but at the same time have domains large enough so that the basin-scale circulation can be simulated better than smaller regional models. Since such models require considerable computational capabilities, the approach taken to optimize the computational load is to use a curvilinear orthogonal grid that has a small grid size in areas rich in mesoscale eddies like the western boundary current, and a coarser grid elsewhere. A fully nested model approach, which has been applied successfully to other applications of POM, will be also considered in the future.

The data assimilation approach is based on standard optimal interpolated methods that have been adapted for oceanic applications together with a vertical projection approach that uses surface-subsurface correlations to project satellite-derived surface observations onto the deep layers (Mellor and Ezer, 1991; Ezer and Mellor, 1994a, 1997b). This approach has been used successfully for assimilation of altimeter data, SST data and frontal position data. This approach is now being evaluated for its usefulness in a basin-scale domains (Ezer and Mellor, 1997c).

WORK COMPLETED

As part of the Data Assimilation and Model Evaluation Experiments in the North Atlantic Basin (DAMEE-NAB), a new high resolution model that extends from 5ºN to 50ºN has been set up; research groups from several institutions who participate in the DAMEE project have set up other models with the same domain for intercomparison studies. The curvilinear grid size ranges between 8 and 35 km, with higher resolution in the Gulf of Mexico and the Gulf Stream area, and lower resolution in the eastern North Atlantic; a model with a 50% larger grid size has been also set up for testing the effect of model resolution on the variability. Sensitivity studies with the two grids have been completed (Ezer, 1997) and are being analyzed in order to determine the effects of grid resolution, horizontal diffusion and viscosity, and open versus closed boundary conditions.

The task of developing data assimilation methodologies for assimilation of SST, altimetry and frontal position data into POM has been completed (Ezer and Mellor, 1997b). An experiment to test the effectiveness of the method in the basin-scale North Atlantic model assimilated with three years of Topex/Poseidon Altimeter data has been completed (Ezer and Mellor, 1997c).

The first stage of the Coastal Ocean Forecast System (in collaboration with NOAA and NRL groups) - establishing the feasibility of a real-time nowcast/forecast system - has been completed; the system has been running smoothly in quasi-operational mode for more than four years, showing continuous improvement in the skill of forecasting tidal and storm surge sea level changes. Implementing the assimilation of satellite data in the operational system is now in progress.

RESULTS

Experiments of the effect of boundary conditions show that the use of a closed boundary at 50ºN and a buffer zone where temperature and salinity are relaxed towards the observed values are not sufficient to produce realistic flows near the boundaries. A more realistic flow and better Gulf Stream separation are achieved when an open boundary condition is used, whereas transports through the boundaries are obtained from a larger-domain climate model. Sensitivity studies quantify how the choice of diffusion, viscosity and grid size affect the model variability. In areas where the model has sufficient resolution, such as in the Gulf of Mexico, model variability is comparable to that observed from altimeter data.

Assimilation of mean surface height obtained from the GDEM climatology together with three years of Topex/Poseidon (T/P) altimeter data into the model brings the model variability closer to the observed variability when compared with an unassimilated model. However, the assimilation of different data sources may need more attention. For example, the assimilated model predicts the mean Gulf Stream position quite accurately in most of the domain (Fig. 1b), but west of 70ºW, the unassimilated model (Fig. 1a) does a better job than the assimilated model, a problem attributed to the fact that the assimilated mean surface height from the GDEM climatology is south of the position observed from AVHRR data.

IMPACT/APPLICATIONS

Continuous improvements in the POM code itself and in data assimilation methods will have an impact on the more than 270 POM users (Ezer, 1996), many of them use the model in the Navy's efforts in coastal modeling and prediction. The development of the operational coastal forecast system has an impact on several small scale regional models of estuaries and bays which will use boundary conditions from this system. It seems quite feasible now to extend the coastal forecast system into a basin-scale nowcast/forecast system that will predict wind-driven and eddy-driven variabilities in real-time.

TRANSITIONS

The transition of the coastal model to a real-time operational forecast system (running daily at NCEP) has been accomplished. A new high resolution North Atlantic model, or a similar extended model, will soon replace the regional model and will form the next generation of operational system for the U.S. east coast and the Gulf of Mexico.

RELATED PROJECTS

In the development and testing of the Coastal Ocean Forecast System (COFS) we collaborate with research groups at NOAA/NCEP and NOAA/NOS. Large scale models that provide boundary conditions for regional forecast systems are developed as part of the Atlantic Climate Change Program (ACCP). We benefit from interactions with scientists working on data assimilation methodologies as part of Princeton University-

GFDL collaboration at the Center for Ocean Data Assimilation and Modeling (CODAM). The DAMEE project provides most of the data for evaluation and assimilation.

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http://www.aos.princeton.edu/WWWPUBLIC/htdocs.pom/CFS The Coastal Ocean Forecast System (COFS) web page.

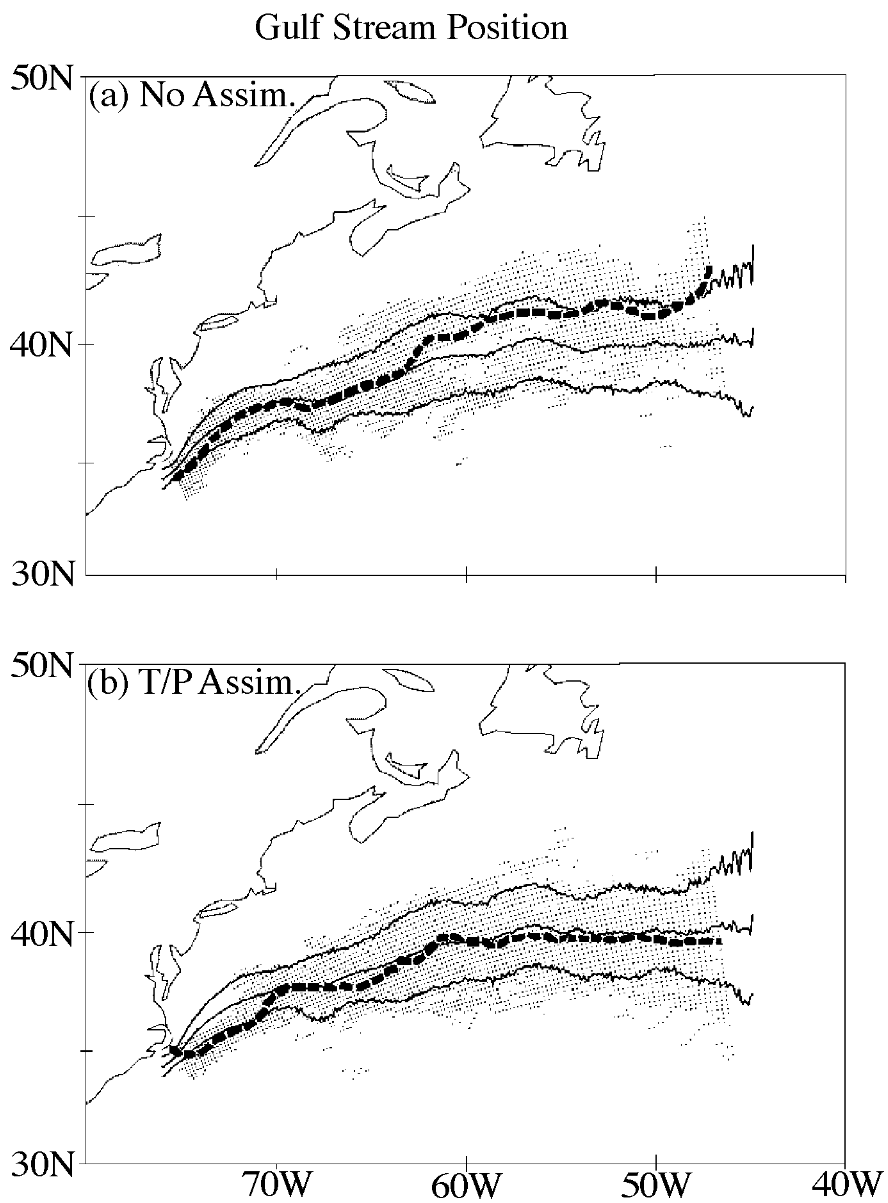

Fig. 1. Three years of model Gulf Stream position (dots) and mean axis (heavy dashed line) obtained from the maximum surface elevation gradient. The Gulf Stream north wall (shifted south 18km to account for the bias between the axis and the north wall) and two standard deviations obtained from AVHRR images are shown in thin lines. (a) Model prediction without data assimilation, and (b) model nowcast with assimilation of GDEM mean elevation and Topex/Poseidon altimeter data.